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[54] **TONE LOCATION DEVICE FOR LOCATING FAULTS IN A PAIRED LINE**

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[63] Continuation-in-part of application No. 08/523,071, Sep. 1, 1995, abandoned.

[51] **Int. Cl.**^{6} **H04M 1/24**

[52] **U.S. Cl.** **379/22**; 379/6; 379/26; 379/27; 324/527; 324/528; 324/530

[58] **Field of Search** 379/1, 6, 21, 22, 379/25, 26, 27, 29–30, 32; 324/500, 512, 527–528, 529–530, 67, 541–542, 539–544; 455/41, 67.4

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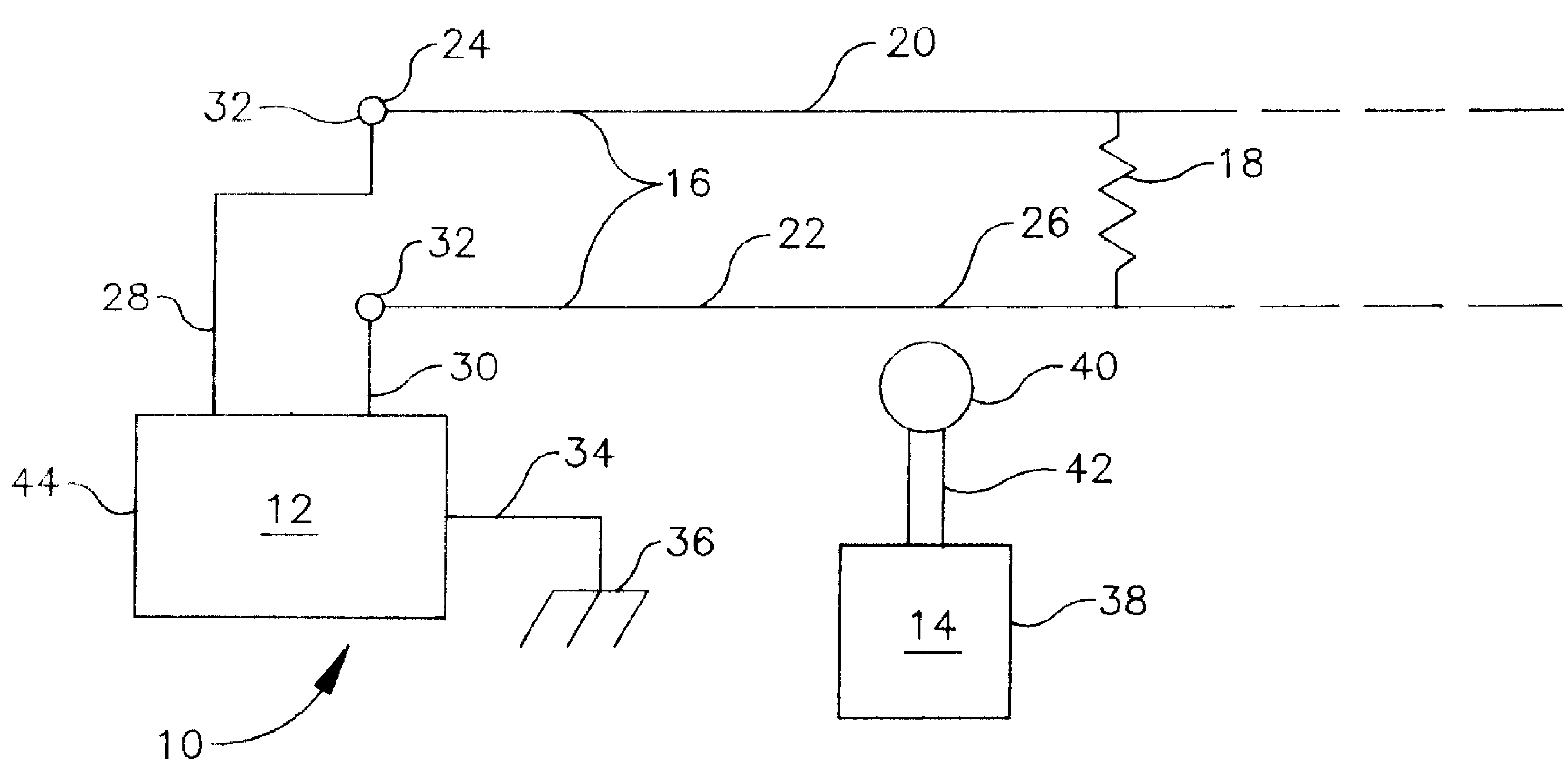
[57] **ABSTRACT**

A device and method are provided for locating faults in a paired line. The fault locating device has a transmitting unit connectable to the conductors of a paired line containing the fault. The device also has a portable receiving unit to track the path of the paired line. The transmitting unit contains circuits for creating and transmitting a locator signal and a carrier signal including synchronization through the conductors toward the receiving unit. The receiving unit contains a pickup coil positioned proximal to the paired line, inducing induced locator and carrier signals in the pickup coil. The receiving unit also contains circuits for processing the induced locator and carrier signals and for producing a synchronization signal used to detect and segregate a component of the induced locator signal which is indicative of a fault. The presence or absence of the indicative component is communicated to an operator by means of an audible or visual fault indicator.

26 Claims, 4 Drawing Sheets



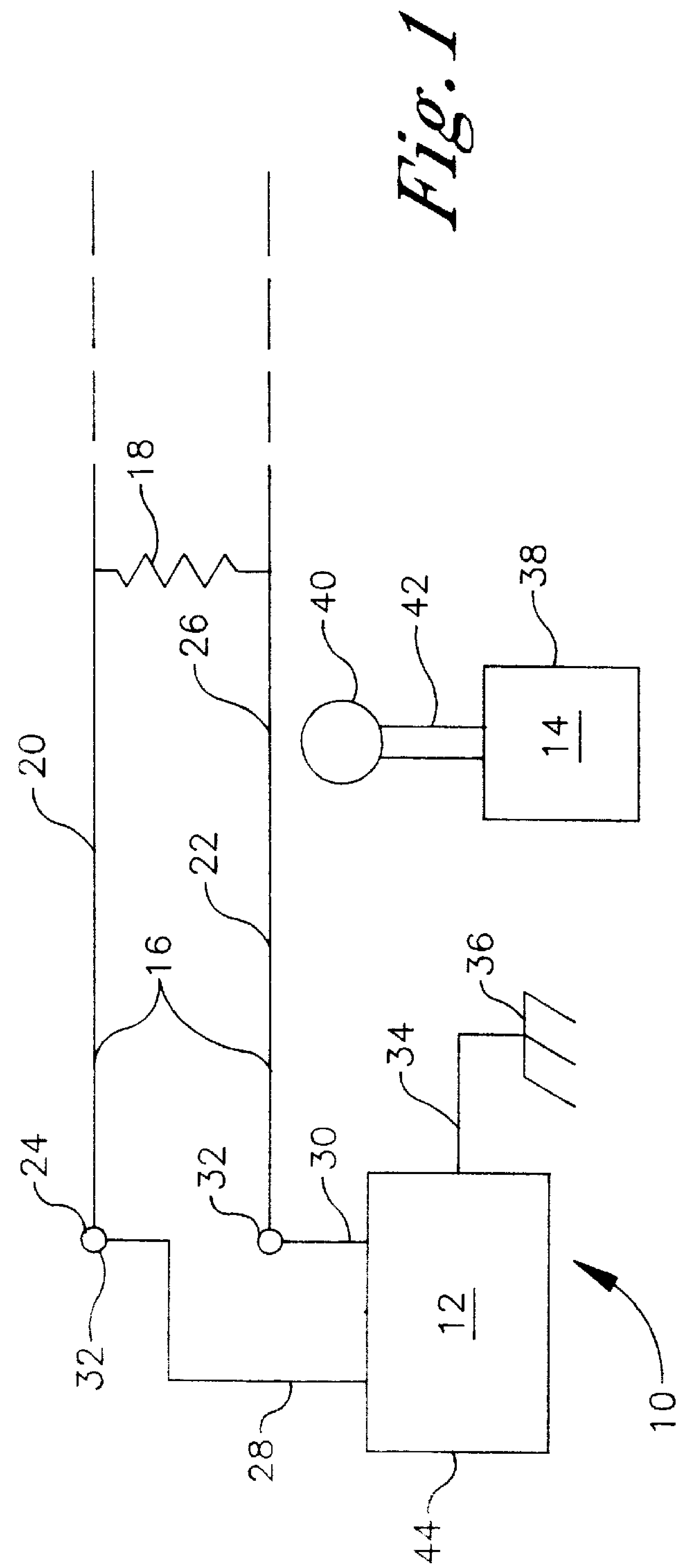


Fig. 1

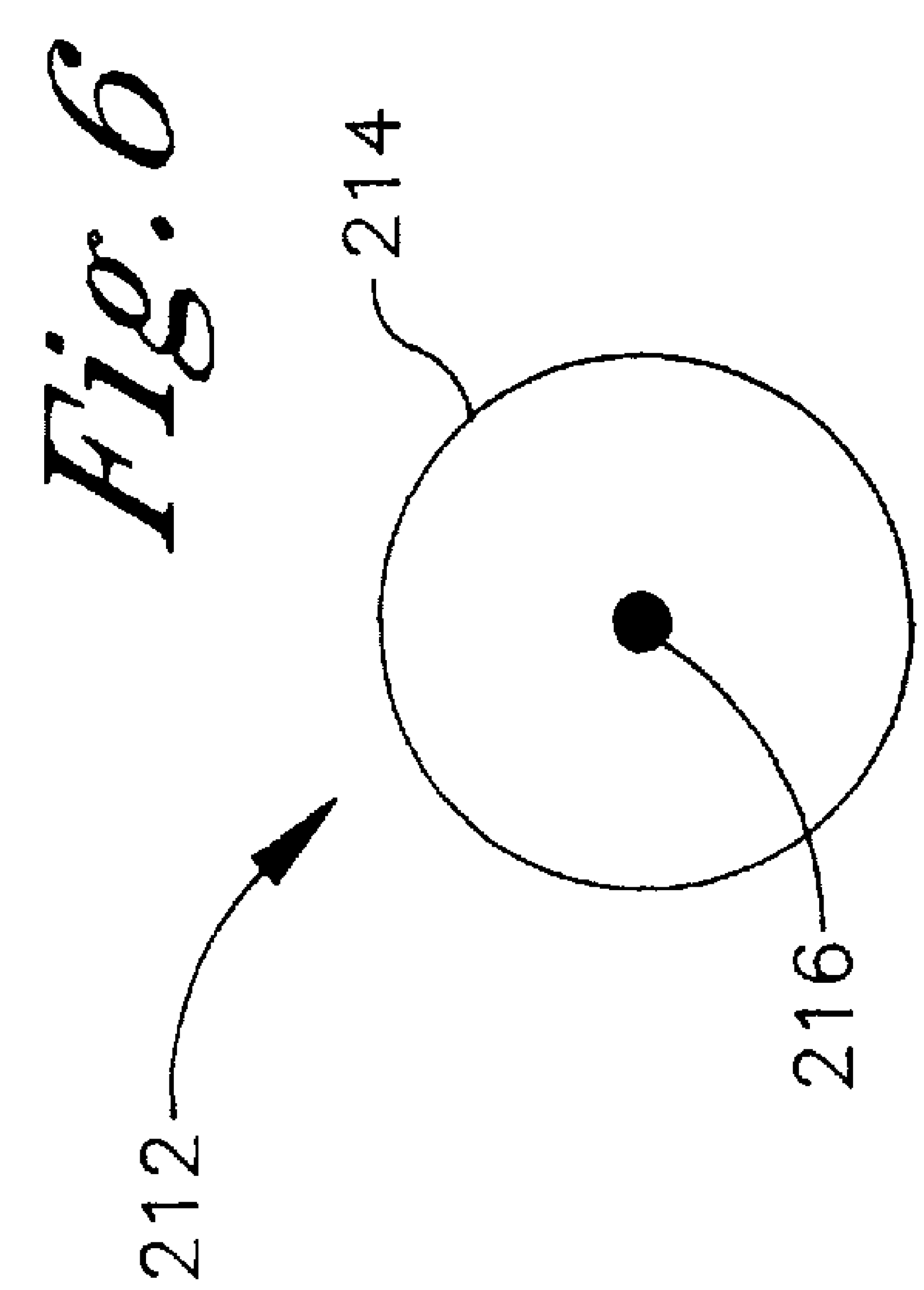


Fig. 6

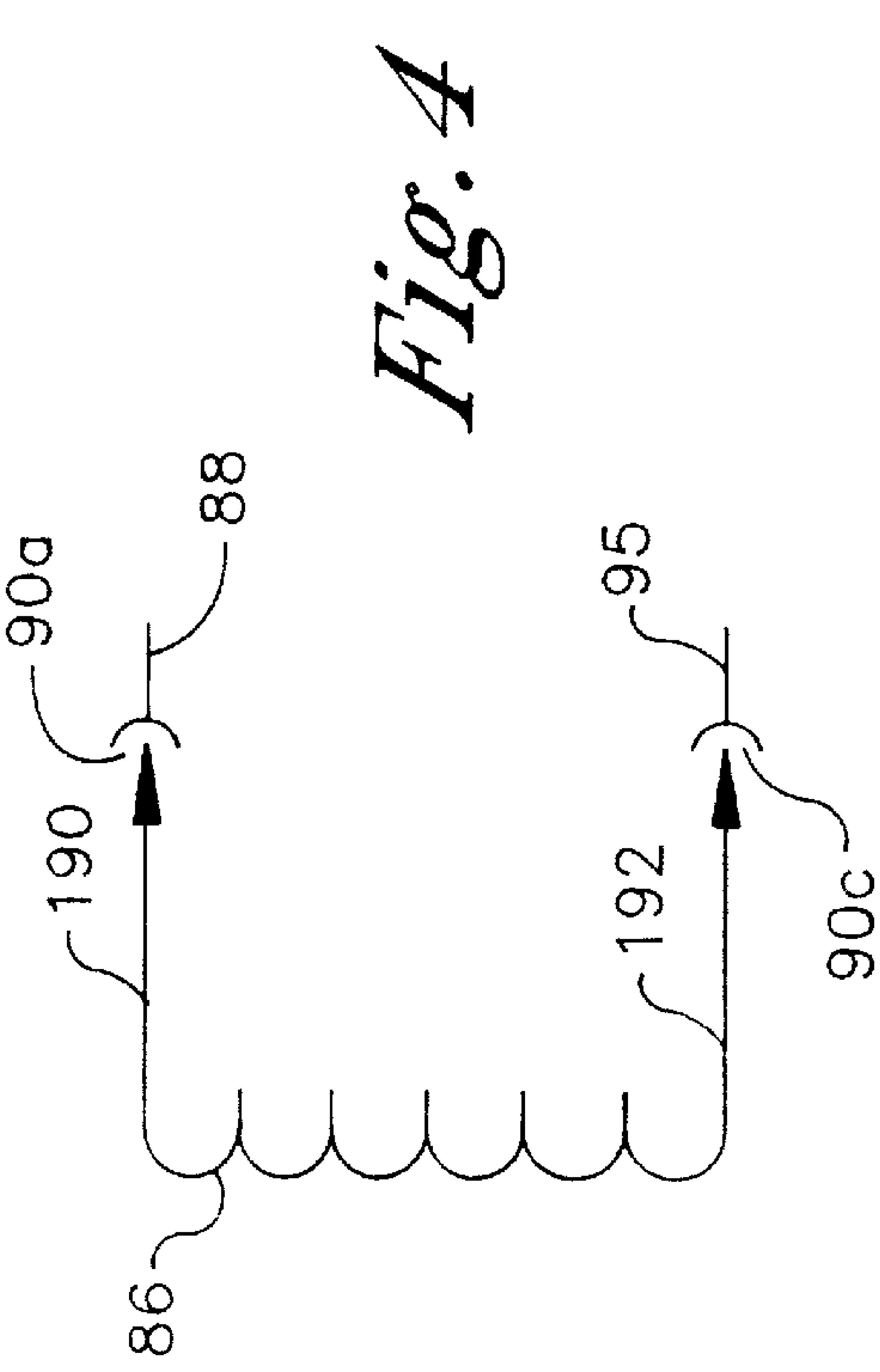


Fig. 4

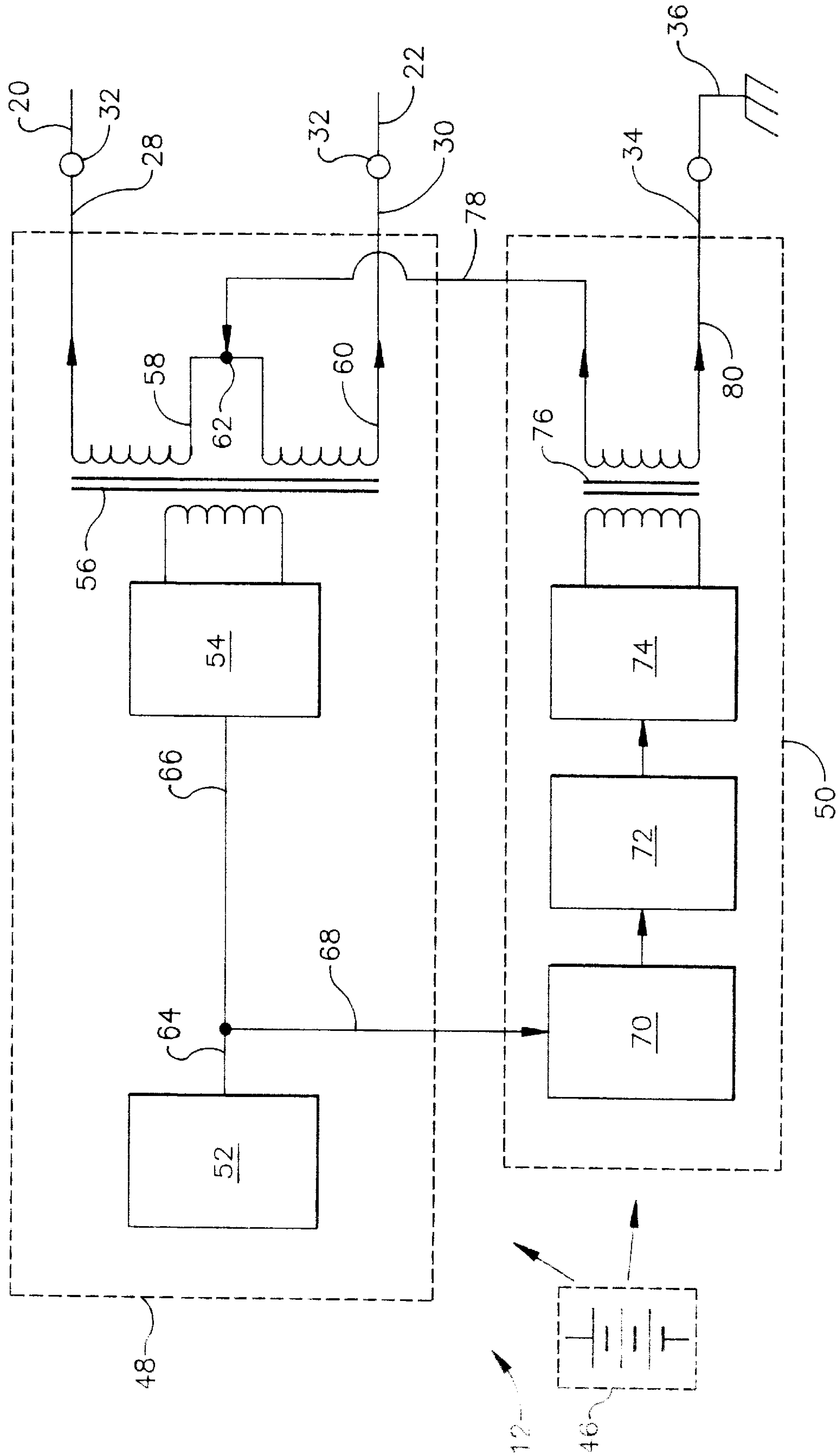

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Fig. 2

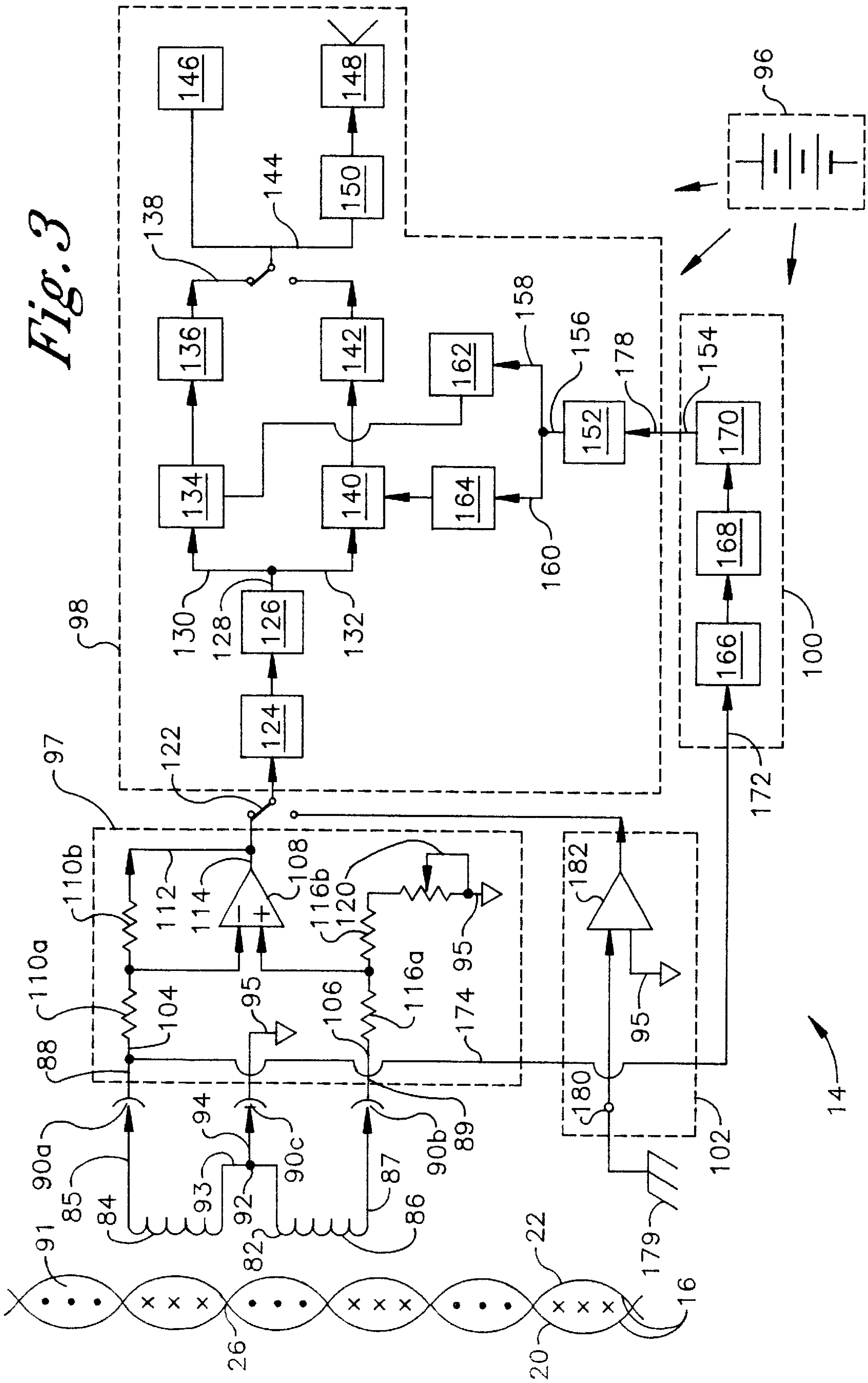


Fig. 3

Fig. 5a

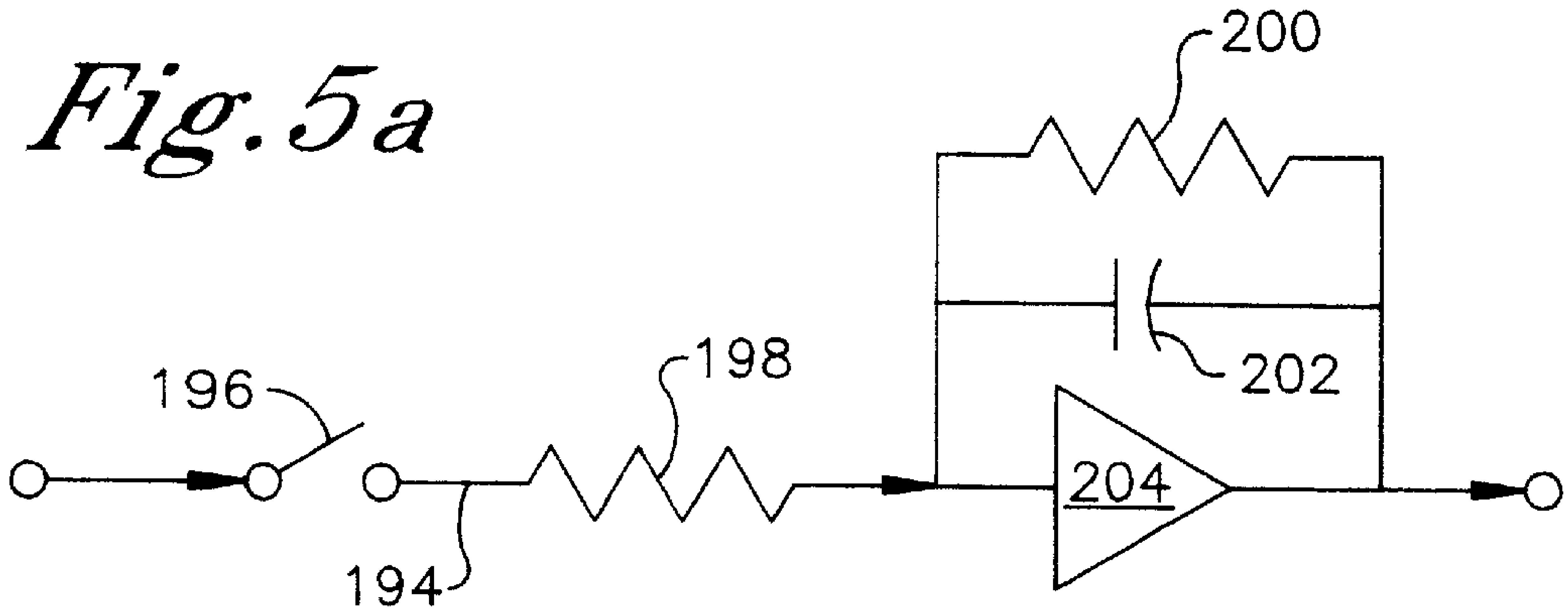
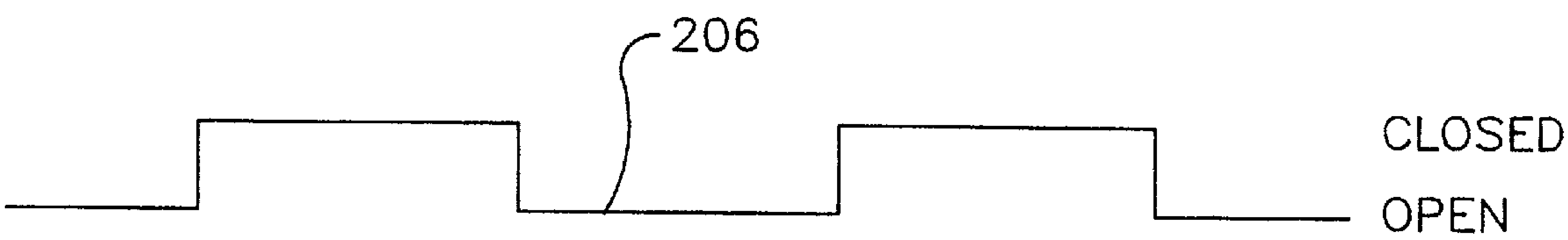


Fig. 5b



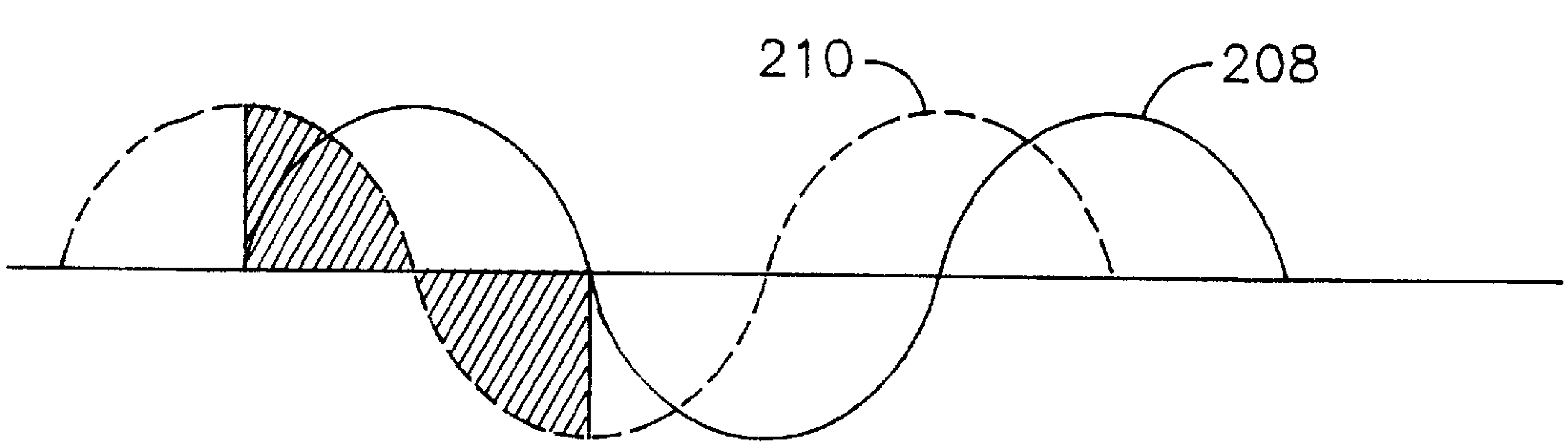


Fig. 5c

TONE LOCATION DEVICE FOR LOCATING FAULTS IN A PAIRED LINE

The present application is a continuation-in-part of application Ser. No. 08/523,071 filed on Sep. 1, 1995 now abandoned.

TECHNICAL FIELD

The present invention relates generally to fault location in a paired line, and more particularly, to a device and method for locating faults in a paired line by monitoring a locator signal introduced into the paired line.

BACKGROUND OF THE INVENTION

A paired line is a conventional means of carrying telecommunications transmissions. A paired line is typically two balanced conductors individually insulated and twisted together along their length. A plurality of paired lines are usually bundled together to form a paired cable containing up to one hundred or more paired lines surrounded by a shield, wherein each paired line of the paired cable is capable of independently carrying a signal. The paired lines of a telecommunications cable are typically spiraled together in groups, having a characteristic spiral pattern termed the lay. A paired line is generally an effective telecommunications carrier, however, a fault can occasionally occur in a paired line limiting the effectiveness thereof. For example, a resistance fault can occur in a paired line when water invades the outer protective covering of a paired cable. The resulting resistance fault is a resistive contact between the two conductors of a paired line within the paired cable. The resistance fault is also often accompanied by a resistance from one of the two conductors of the paired line to ground or to another conductor of the paired cable. Another type of fault can occur when there is a discontinuity or break in the shield of the paired cable. The fault allows an increased coupling of extraneous voltages into one or more enclosed paired lines of the paired cable from nearby sources, such as power transmission cables. An open conductor fault or an underdesired bridged tap is a fault which interrupts current flow through a paired line or unbalances the paired line, diminishing the effectiveness of the paired line for telecommunications applications.

Such faults typically cause noise in the affected paired line that is extremely disruptive to the clarity of the telecommunications signal sent over the paired line. A disruptive to the clarity of the telecommunications signal sent over the paired line. A fault in a paired line can also cause other problems such as circuit failure, arc-over and corrosion. Therefore, it is desirable to locate and repair faults in a paired line, particularly a paired line in a telecommunications cable

Since telecommunications cables are not always readily accessible, often being buried below ground, noninvasive methods are preferred for locating faults in a paired line of a telecommunications cable. Tone location methods are conventional noninvasive means for locating a short fault in a paired line of a telecommunications cable using an audible tone as a locator signal. However, tone location methods are often ineffective for locating most resistance faults in a paired line. One reason for such ineffectiveness is a phenomenon termed carry-by. Carry-by occurs at faults that exceed a threshold resistance typically above about 2000 ohms. Most resistance faults have a resistance in a range between about 5000 to about 50,000 ohms. When a resistance exceeding the threshold resistance for carry-by is encountered at the resistance fault in a paired line, the current of the audible tone produces a voltage across the conductors of the paired line past the fault. This voltage causes a corresponding tone current to flow into pair capacitance beyond the fault. Thus, a tone will be audible beyond the resistance fault defeating the tone location method. The problem of carry-by is particularly acute when a high-frequency tone is present in the paired line because the magnitude of tone current flow past the fault is directly related to the frequency of the tone.

It is further noted that less tone current is typically driven through the paired line as the level of fault resistance increases. At relatively high levels of resistance, such as encountered in resistance faults, the level of tone current available for detection can drop below the background noise level present on a paired cable. Consequently, the background noise masks the location of the fault.

Alternate tone location methods have been developed in the telephone industry for detecting resistance faults, which overcome the above-described limitations caused by carry-by. For example, one alternate tone location method uses a 600-volt, breakdown test set to weld the conductors of the paired line together at the fault, which reduces fault resistance to zero in the paired line, thereby allowing effective tone location of the resistance fault. This tone location method, however, can cause extensive cable and equipment damage, particularly to plastic insulated cable and electronic central offices due to the high breakdown voltages used. Accordingly, this tone location method for overcoming fault resistance is disfavored.

Another alternate tone location method for locating resistance faults is disclosed in U.S. Pat. No. 4,291,204, wherein a tone locating device temporarily reduces the fault resistance to a low value by establishing a transient arc at the fault. Passing the fault locating tone through the low-resistance arc at the fault reduces tone carry-by, but does not entirely eliminate it. In addition, the conductors and equipment are susceptible to damage caused by formation of the transient arc, albeit to a lesser degree than the damage potential of the previously described tone location method.

Accordingly, it is an object of the present invention to provide a device and method for effectively locating faults in a paired line using a locator signal. In particular, it is an object of the present invention to provide a device and method for effectively locating resistance faults in a paired line using a locator signal. It is another object of the present invention to provide a device for effectively locating open faults or bridged taps in a paired line using a locator signal. It is yet another object of the present invention to provide a device and method for effectively locating shield break faults in a paired cable. It is another object of the present invention to provide a device and method for effectively locating faults in a paired line using a locator signal, wherein background noise is overcome. It is still another object of the present invention to provide a device and method for effectively locating faults using a locator signal, wherein the impact of carry-by is minimized. It is a further object of the present invention to provide a device and method for effectively locating faults in a paired line using a locator signal, wherein the device is fully portable in the field for expeditiously tracking relatively long lengths of the paired line. These objects and others are accomplished in accordance with the invention described hereafter.

SUMMARY OF THE INVENTION

The present invention is a device and method for locating a fault in a paired line. The device and method are particularly applicable to the location of a resistance fault in a paired line of a telecommunications cable. The fault locating device comprises a transmitting unit and a receiving unit.

The transmitting unit is electrically coupled with the two conductors of a paired line believed to contain a fault. The transmitting unit has internal circuitry, including a power source, a locator signal transmission circuit having a locator signal output, and a carrier signal transmission circuit having a carrier signal output. The locator signal transmission circuit is configured to create a locator signal, convert the locator signal to two locator signals of opposite polarity, and introduce the polar opposite locator signals into the respective conductors of the paired line. The carrier signal transmission circuit is configured to create a carrier signal, provide the carrier signal with modulated synchronization, and introduce the modulated carrier signal into the conductors of the paired line.

The receiving unit is portable, enabling an operator to track the path of the conductors with the receiving unit. The receiving unit has internal circuitry and an associated pickup coil, preferably having a balanced configuration. The pickup coil is positioned proximal to the conductors of the paired line, providing magnetic coupling with the conductors, but avoiding electrical contact with the conductors. The balanced pickup coil is configured such that two induced locator signals of opposite polarity and an induced carrier signal are simultaneously induced in the pickup coil in response to the polar opposite locator signals and carrier signal traveling through the conductors. The internal circuitry of the receiving unit includes a power source, an induced locator signal balancing/amplifying circuit, an induced locator signal processing circuit having a component detector, an induced carrier signal processing circuit having a synchronization signal output, and a capacitive signal processing circuit. The induced locator signal balancing/amplifying circuit is configured to produce a balanced induced locator signal from the two induced locator signals of opposite polarity, thereby minimizing the effect of noise in the receiving unit. The induced locator signal processing circuit is configured to detect first and second components of the balanced induced locator signal indicative of first and second types of faults, respectively, segregate the first and second indicative components from one another, and communicate the presence of either indicative component to the operator in the form signal processing circuit is configured to receive the induced carrier signal from the pickup coil and demodulate the induced carrier signal, and transmit the resulting demodulated synchronization signal to the induced locator signal processing circuit. The induced locator signal processing circuit produces first and second synchronization signals from the demodulated synchronization signal, which correspond to the first and second components of the balanced induced locator signal. The first and second synchronization signals are utilized to detect and segregate the first and second components of the balanced induced locator signal. The capacitive signal processing circuit is configured to create a differential capacitive signal from a locator signal on the cable shield and communicate a fault indicator to the operator in response to the differential capacitive signal.

Operation of the present fault locating device is performed by connecting the transmitting unit in electrical communication with both conductors of the paired line and positioning the receiving unit proximal to the paired line adjacent to the transmitting unit. The transmitting unit introduces the polar opposite locator signals and the modulated carrier signal into the conductors of the paired line. The locator and carrier signals travel along the conductors to induce the induced locator and carrier signals in the balanced pickup coil. The receiving unit processes the resulting induced locator and carrier signals to detect and segregate the components of the induced locator signal. The receiving unit continuously communicates the presence or absence of a component indicative of a fault to the operator by means of a fault indicator.

The operator incrementally repositions the receiving unit away from the transmitting unit along the path of the paired line as operation of the fault locating device proceeds. As the receiving unit approaches the fault, the intensity or frequency of the fault indicator remains substantially constant. However, when the receiving unit passes the fault so that the fault is between the receiving unit and the transmitting unit, the intensity or frequency of the fault indicator abruptly drops, thereby establishing the precise location of the fault.

In accordance with an alternate method of operation, shield break faults are located by introducing a locator signal into the paired line. A capacitive signal is created in the pickup coil in response to the locator signal in the paired line, wherein the pickup coil is a capacitive pickup functioning as a capacitor. The capacitive signal is received by the capacitive signal processing circuit, which is referenced to ground. The capacitive signal is converted to a differential capacitive signal utilizing the ground reference. The receiving unit continually communicates the value of the differential capacitive signal to the operator by means of a fault indicator.

The operator incrementally repositions the receiving unit away from the transmitting unit along the path of the paired line as operation of the fault locating device proceeds. As the receiving unit approaches the shield break fault, the intensity or frequency of the fault indicator remains substantially constant. However, when the receiving unit reaches the shield break fault, the intensity or frequency of the fault indicator abruptly increases, thereby establishing the precise location of the shield break fault.

The present invention will be further understood, both as to its structure and operation, from the accompanying drawings, taken in conjunction with the accompanying description, in which similar reference characters refer to similar parts.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a conceptual view of a fault locating device of the present invention operably positioned in relation to a paired line.

FIG. **2** is a block diagram of the transmitting unit shown in the device of FIG. **1**.

FIG. **3** is a block diagram of the receiving unit shown in the device of FIG. **1**.

FIG. **4** is a conceptual view of an alternate pickup coil configuration having utility in the fault location device of the present invention.

FIGS. **5***a*, **5***b*, **5***c* depict conceptualized operation of a synchronous detector employed in the receiving unit of FIG. **3**.

FIG. **6** is a conceptual cross-sectional view of a shielded cable, to which the fault location device of the present invention is applied, for detecting a shield break.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring initially to FIG. **1**, a fault locating device of the present invention is shown and generally designated **10**. The fault locating device **10** has two basic components comprising a transmitting unit **12** and a receiving unit **14**. The fault locating device **10** is operably positioned relative to a paired line **16**, in which it is desired to locate a fault **18**, such that the transmitting unit **12** engages a first conductor **20** and a second conductor **22** of the paired line **16** at a transmission point **24** on the paired line **16**.

The fault locating device **10** of the present invention has general utility to paired lines employed in paired cables for a number of different applications, including power transmission and communications. As defined herein, a paired line is substantially any line having at least two continuous electrical conductors that, in the absence of a fault, are electrically insulated from one another. The two conductors can each be solid or braided wires, grounded or ungrounded and having parallel or spiral paths. Alternatively, one conductor can be a wire and the other conductor can be a conductive tubular shield enclosing the wire. The above-recited definition of a paired line encompasses coaxial cable, shielded cable, and cable having more than two conductors, wherein any two conductors of the cable may be deemed to define a paired line for purposes of the invention. For example, a paired line as defined herein includes a shielded cable having a shield and a conductor enclosed within the shield. The fault locating device **10** has particular utility to twisted paired lines employed in paired cable for telecommunications applications, including accessible paired cables, such as aerial paired cables, and inaccessible paired cables, such as buried paired cables.

A fault is defined herein as any unintended perturbation in the path of a conductor that undesirably draws current therefrom, such as a short, an open, a cross, a ground, a split, or a shield break. The present fault locating device **10** is applicable to the location of many types of faults as generally defined above.

The receiving unit **14** is operably positioned proximal to a reception point **26** on the paired line **16** that is between the transmission point **24** and the fault **18**. As such, the receiving unit **14** preferably does not electrically contact the conductors **20, 22**, but is sufficiently proximal to the conductors **20, 22** to induce induced locator and carrier signals in the receiving unit **14** as will be described hereafter. The transmission point **24** is preferably selected at a point on the paired line **16** where relatively convenient electrical access to the conductors **20, 22** is provided, such as a junction box or other splice location. Electrical communication is provided between the transmitting unit **12** and the conductors **20, 22** by test leads **28, 30** extending from the transmitting unit **12**. The test leads **28, 30** have electrically conductive connectors **32**, such as conventional alligator clips or the like, on their ends which are removably connected to the conductors **20, 22**. A ground lead **34** is also provided, connecting the transmitting unit **12** in electrical communication with a ground **36**.

As will be described in greater detail hereafter with respect to the method of operation, the position of the transmission point **24**, and correspondingly the position of the transmitting unit **12**, are substantially fixed relative to the paired line **16** during a given fault locating sequence. In contrast, the position of the reception point **26**, and correspondingly the position of the receiving unit **14**, are variable along the length of the paired line **16** throughout a given fault locating sequence. Accordingly, the receiving unit **14** has a fully mobile, unanchored, portable configuration. The receiving unit **14** is relatively compact and lightweight to render it manually transportable by a single operator. In the embodiment of FIG. **1**, the receiving unit **14** is shown to comprise a unitary housing **38** and a probe **40** positioned outside the housing **38**. A connective member **42** extends between the probe **40** and the housing **38**. The housing **38** is preferably a hardened protective shell and the connective member **42** is typically an electrically conductive wire extending between the housing **38** and the probe **40**, functioning in a manner described hereafter. The connective member **42** may further include a flexible or rigid pole supporting the electrically conductive wire. Although not shown, the probe **40** can alternatively be positioned within the housing **38**, thereby eliminating the connective member **42** external to the housing **38**.

The specific components of the transmitting unit **12** are described with further reference to the block diagram of FIG. **2**. Substantially all of the circuitry of the transmitting unit **12** is enclosed in a housing **44** (shown in FIG. **1**) comprising a hardened protective shell. The circuitry of the transmitting unit **12** includes a power source **46**, a locator signal transmission circuit **48** and a carrier signal transmission circuit **50**. As described above, the test leads **28, 30** extend from the transmitting unit **12** and removably connect with the conductors **20, 22** to provide electrical communication between the circuits **48, 50** and the paired line **16**. The locator signal transmission circuit **48** is configured to generate and send locator signals along the conductors **20, 22** of the paired line **16** from the transmission point **24** toward the reception point **26**. Included within the locator signal transmission circuit **48** is a locator signal output **52**, which in the present embodiment is a locator signal oscillator. It is apparent to the skilled artisan that alternate locator signal outputs are possible within the scope of the present invention. The locator signal transmission circuit **48** further includes in series a locator signal driver **54**, and a locator signal transformer **56**. The outlet of the locator signal transformer **56** is segmented into a first outlet winding **58** and a second outlet winding **60** which are electrically coupled with the transmission lines **28, 30**, respectively. A center tap **62** is provided between the two outlet windings **58, 60**. The outlet line **64** of the locator signal output **52** is branched, with one branch line **66** extending to the locator signal driver **54** as described above and the other branch line **68** extending to the carrier signal transmission circuit **50**.

The carrier signal transmission circuit **50** is configured to generate a carrier signal, provide the carrier signal with modulated synchronization, and transmit the modulated carrier signal along the conductors **20, 22** of the paired line **16** from the transmission point **24** toward the reception point **26**. Included in series within the carrier signal transmission circuit **50** are a zero crossing detector **70**, a carrier signal output **72**, a carrier signal driver **74**, and a carrier signal transformer **76**. In the present embodiment, the carrier signal output **72** is a carrier signal oscillator. It is apparent to the skilled artisan that alternate carrier signal outputs are possible within the scope of the present invention. One outlet **78** of the carrier signal transformer **76** is electrically coupled with the center tap **62** of the locator signal transformer **56** and the other outlet **80** of the carrier signal transformer **76** extends through the ground leads **34** to ground **36** or to a cable shield (not shown), which functions as a ground.

The power source **46** is a DC power source included in the housing **44** of the transmitting unit **12**. The power source **46** supplies power to the components of the transmitting unit **12** enabling the functions thereof. The power source **46** is preferably a relatively small, lightweight battery pack, such as one or more dry-cell or rechargeable batteries (e.g., D-cell batteries).

It is noted that the zero crossing detector **70** can be omitted from the transmitting unit **12** without disabling operation of the transmitting unit **12**, as will be described hereafter.

The specific components of the receiving unit **14** are described with further reference to the block diagram of FIG. **3**. The probe **40** (shown in FIG. **1**) encloses a pickup coil **82** electrically coupled with the circuitry if the receiving unit **14**. The pickup coil **82** has a balanced configuration which has specific utility for locating faults in an inaccessible paired line as will be described hereafter. It is understood that alternately configured pickup coils can be utilized, depending on the specific application of the fault locating device **10**. The balanced pickup coil **82** is relatively large, typically having an elongated magnetic core or core of other geometry sufficient to meet the performance requirements of the receiving unit **14**. The balanced pickup coil **82** includes a first coil segment **84** having a first coil outlet line **85** and a second coil segment **86** having a second coil outlet line **87**. The first and second coil outlet lines **85**, **87** in cooperation with first and second receiving circuitry inlet lines **88**, **89**, respectively, electrically couple the first and second coil segments **84**, **86** with the circuitry of the receiving unit **14**. Male/female connectors **90***a*, **90***b* such as conventional telephone jacks, are provided to releasably connect the first and second coil outlet lines **85**, **87** and the first and second receiving circuitry inlet lines **88**, **89**, respectively. The connectors **90***a*, **90***b* enable the substitution of alternately configured coils for the balanced coil **82**, such as described hereafter.

The spacing between the first and second coil segments **84**, **86** which is defined as the distance between the midpoints of the segments, **84**, **86** is about equal to one half the length of the lay of the paired line **16**, wherein the paired line **16** is shown to be twisted and spiraled in the conventional manner of a telecommunications cable. The length of the lay for telecommunications cable is commonly about 36 inches and the current direction in each adjacent loop **91** of the lay differs by 180°. Thus, the first and second coil segments **84**, **86** are phased due to the 18 inch spacing between the coil segments **84**, **86** and the corresponding 36 inch length of the cable lay. The pickup coil **82** further includes a center tap **92** positioned on a coil common **93**, which connects the first and second coil segments **84**, **86**. A third coil outlet line **94** extends from the center tap **92** through a connector **90***c*, similar to those described above, to a receiving unit common **95**.

The circuitry of the receiving unit **14** includes a power source **94**, an induced locator signal balancing/amplifying circuit **97**, an induced locator signal processing circuit **98**, an induced carrier signal processing circuit **100**, and a capacitive signal processing circuit **102**. The induced locator signal balancing/amplifying circuit **97** provides an electrical pathway for noise nulling in the receiving unit **14**. The induced locator signal balancing/amplifying circuit **97** comprises a first balancing inlet pathway **104** and a second balancing inlet pathway **106** positioned in parallel. The first balancing inlet pathway **104** and the second balancing inlet pathway **106** are electrically coupled with the first coil segment **84** and the second coil segment **86** through the first and second receiving circuitry inlet lines **88**, **89**, connectors **90***a*, **90***b*, and first and second coil outlet lines **85**, **87**, respectively. Each balancing inlet pathway **104**, **106** provides an inlet to a balancing amplifier **108**. The first balancing inlet pathway **104** includes a pair of balancing resistors **110***a*, **110***b* and has a feedback line **112** electrically coupled with the outlet **114** of the balancing amplifier **108**. The second balancing inlet pathway **106** also includes a pair of balancing resistors **116***a*, **116***b* and a branch line **118**. The branch line **118** is electrically coupled with a balancing potentiometer **120**, enabling balance adjustment of the pickup coil **82**.

The induced locator signal balancing/amplifying circuit **97** selectively electrically communicates with the induced locator signal processing circuit **98** through a first switch **122** at the outlet **114** of the balancing amplifier **108** downstream of the branch line **112**. The induced locator signal processing circuit **98** provides an electrical pathway capable of producing an audible or visual fault indicator for an operator in response to a balanced induced locator signal. When the first switch **122** is appropriately positioned, the balancing amplifier **108** of the induced locator signal balancing/amplifying circuit **97** is electrically coupled in series with a variable gain amplifier **124** and a band pass filter **126** of the induced locator signal processing circuit **98**. The outlet **128** of the band pass filter **126** splits into a real component pathway **130** and a quadrature component pathway **132**. The real component pathway **130** includes in series a real synchronous detector **134** and a real low pass filter **136**, which lead to a second switch **138**. The quadrature component pathway **132** similarly includes in series a quadrature synchronous detector **140** and a quadrature low pass filter **142**, which lead to the second switch **138**. The second switch **138** selectively electrically couples the real component pathway **130** or the quadrature component pathway **132** with an indicator output **144** of the induced locator signal processing circuit **98**. The indicator output **144** comprises in parallel a display **146** and an audio speaker **148**, having an associated output oscillator **150**. The indicator output **144** enables the receiving unit **14** to communicate a fault indicator both visually and audibly to an operator of the device **10**.

The induced locator signal processing circuit **98** is in electrical communication with the induced carrier signal processing circuit **100** by means of a phase shifter **152** electrically coupled with the outlet **154** of the induced carrier signal processing circuit **100**. The outlet **156** of the phase shifter **152** splits into a real synchronization pathway **158** and a quadrature synchronization pathway **160**. The real synchronization pathway **158** has a real synchronous oscillator **162** that is electrically coupled with the real synchronous detector **134**. The quadrature synchronization pathway **160** similarly has a quadrature synchronous oscillator **164** that is electrically coupled with the quadrature synchronous detector **140**. Although the real and quadrature synchronous oscillators **162**, **164** are shown herein to be separate components, it is apparent to the skilled artisan that the oscillators **162**, **164** can be replaced by a single oscillator or a microcontroller delivering real and quadrature synchronization signals in the same manner as described above.

The induced carrier signal processing circuit **100** provides an electrical pathway for producing and communicating a demodulated synchronization signal to the induced locator signal processing circuit **98**. Included in series within the induced carrier signal processing circuit **100** are an induced carrier signal amplifier/receiver **166**, an induced carrier signal limiter **168** and a synchronization signal output **170**. In the present embodiment, the synchronization signal output **170** is a carrier signal demodulator. It is apparent to the skilled artisan that alternate synchronization signal outputs are possible within the scope of the present invention. As used herein, the term "limiter" is defined to encompass a conventional limiter or, in the alternative, an automatic gain control. The inlet **172** of the carrier signal amplifier/receiver **166** is electrically coupled with the first coil segment **84** via the receiving circuitry inlet line **88** and a receiving circuitry outlet line **174**. The outlet **154** of the synchronization signal output **170** is electrically coupled with the inlet **178** of the phase shifter **152**.

The capacitive signal processing circuit **102** selectively electrically communicates with the induced locator signal processing circuit **98** through the first switch **122**. The capacitive signal processing circuit **102** in cooperation with the induced locator signal processing circuit **98** provides an electrical pathway capable of producing an audible or visual fault indicator for an operator in response to a capacitive signal. The capacitive signal processing circuit **102** includes in series a ground **179**, a ground pickup **180** and a capacitive signal amplifier **182**. If the housing **38** of the receiving unit **14** is electrically conductive, the ground pickup **180** is simply the housing **38**. If the housing **38** is not electrically conductive, the ground pickup **180** can be provided by an electrical conductor, such as a metallic shield (not shown) contained within the housing **38**. The ground pickup **180** is electrically coupled with the body of an operator (not shown) to provide the ground **179** and corresponding ground reference when the operator is standing on the earth. When the first switch **122** is appropriately positioned, the capacitive signal amplifier **182** of the capacitive signal processing circuit **102** is electrically coupled with the variable gain amplifier **124** and band pass filter **126** of the induced locator signal processing circuit **98**.

The power source **96** is a DC power source included in the housing **38** of the receiving unit **14**. The power source **96** supplies power to the components of the receiving unit **14** enabling the functions thereof. The power source **96** is preferably a relatively small, lightweight battery pack, such as described above with respect to the transmitting unit **12**.

It is noted that the carrier signal amplifier/receiver **166** is shown and described herein as integrated into a single structure. In practice, this integrated structure can be separated into discrete structural components performing the same functions ascribed to the integrated structure in a manner apparent to the skilled artisan.

Referring to FIG. **4**, an alternate nonbalanced pickup coil **186** is shown, which is substituted for the **82** balanced pickup coil. The nonbalanced pickup coil **186**, which is a relatively small contact coil with a single coil segment and two outlets **190**, **192**, has specific utility for locating faults in an accessible paired line **16**. The first outlet **190** is electrically coupled with the first balancing inlet pathway **104** through the connector **90***a* and the second outlet **192** is electrically coupled with the receiving unit common **95** through the connector **90***c*, while the second balancing inlet pathway **106** is open circuited. As a result, the balancing potentiometer **120** is rendered nonfunctional, while the balancing amplifier **108** functions as an unbalanced input amplifier.

Method of Operation

Operation of the fault locating device **10** is initially described with reference to FIGS. **1–3**. The method of operation is initiated by identifying a paired line **16** that is believed to contain the fault **18**. For purposes of illustrating a first embodiment of the method of the present invention, the fault **18** is characterized as a resistance fault and, more particularly, as a short fault. The paired line **16** is typically up to about 5000 meters in length, although practice of the present fault locating method applies to paired lines **16** of substantially greater length. An operator fixably positions the transmitting unit **12** at a transmission point **24** on the paired line **16**. The test leads **28**, **30** are removably connected to the first and second conductors **20**, **22** at the transmission point **24** and the ground lead **34** is removably connected to ground **36** or the cable shield (not shown). The DC power source **46** energizes the locator signal output **52** and locator signal driver **54** of the locator signal transmission circuit **48**, which generate an AC locator signal in the form of a variable voltage sine wave. The locator signal is delivered to the locator signal transformer **56** where the voltage of the locator signal is adjusted to a predetermined level. The first aid second outlet windings **58**, **60** of the locator signal transformer **56** convert the locator signal to a first locator signal and a second locator signal, respectively, which have substantially identical voltage, but opposite polarity. The resulting first and second locator signals are introduced into the first and second conductors **20**, **22**, respectively, through the test leads **28**, **30**, respectively.

The variable voltage sine wave of the locator signal output **52** is also transmitted to the carrier signal transmission circuit **50** where the sine wave is converted to a square wave in the zero crossing detector **70**. The square wave signal is then modulated in the carrier signal output **72**, which is a voltage control oscillator, by frequency shift key modulation to produce a carrier signal having modulated synchronization. The resulting carrier signal is fed through the carrier signal driver **74** to the carrier signal transformer **76** where the voltage of the carrier signal is modified. The carrier signal is then introduced into each of the conductors **20**, **22** via the outlet **78** of the carrier signal transformer **76**, the center tap **92**, the outlet windings **58**, **60**, and the test leads **28**, **30** of the locator signal transmission circuit **48**.

It is understood that the present invention can alternatively be practiced using a sine wave carrier signal rather than the square wave carrier signal described above. In accordance with this embodiment, the zero crossing detector **70** is omitted from the fault locating device **10** and the induced carrier signal processing circuit **100** is configured to process a sine wave, rather than a square wave, by varying the frequency of the carrier signal output **72** sinusoidally, in a manner readily apparent to the skilled artisan, in place of frequency shift key modulation.

The voltage and frequency of the locator and carrier signals are preferably limited to ranges that satisfy desirable performance criteria of the fault locating device **10**. In particular, the voltage and frequency ranges of the locator signals are preferably selected at the upper end to avoid excessive carry-by of the locator signal on the paired line **16**. Generally, a signal having both a very low voltage and a very low frequency avoids significant carry-by. Such a signal, however, may fail to satisfy other performance criteria of the device **10**, lacking sufficient voltage to exceed the background noise or sufficient frequency to enable detection. If the frequency of the locator signals is raised to improve the detectability thereof, the locator signals may become overly susceptible to carry-by. Alternatively, if the voltage of the locator signals is raised to overcome the background noise, excessive battery power may become necessary.

Selection of the voltage and frequency of the locator signals may require a balancing of competing factors to achieve a fully-portable fault locating device **10** having detectable locator signals that exceed the background noise on the paired line **16** while avoiding the effects of excessive carry-by. Achievement of these performance criteria is facilitated by noise nulling means that reduce the noise induced in the pickup coil **82**, and by synchronization circuitry that mitigates the impact of carry-by, as described hereafter. As such, the frequency of the locator signals is typically selected in the RF, audible, or sub-audible range. A preferred range is less than about 20,000 Hz, more preferably in a range between about 20,000 Hz and about 1 Hz, and most preferably in a range between about 1,500 and about 10 Hz. The voltage of the locator signals is typically selected in a range between about 1 volt and about 150 volts and on each conductor **20**, **22**, and preferably at a value of about 25 volts. The frequency of the induced locator signals is substantially identical to that of the transmitted locator signals, but the voltage is typically selected in a range between about 0.1 microvolt and 1000 microvolts and preferably at a value of about 10 microvolts, which is generally greater than ambient noise. The carrier signal has a frequency range greater than about 5 kHz, and preferably between about 5 kHz and about 100 kHz. The carrier signal typically has a voltage below about 150 volts within the prescribed frequency range and preferably has a voltage of about 25 volts.

The present method of locating the fault **18** proceeds by positioning the probe **40** of the receiving unit **14** proximal to a selected reception point **26** on the paired line **16**, preferably between the transmission point **24** and the fault **18**. The actual position of the reception point **26** is variable, rather than fixed, during operation of the fault locating device **10**. The reception point **26** is preferably positioned near the transmission point **24** during initial operation of the device **10**. The reception point **26** is then incrementally repositioned away from the transmission point **24** as operation of the device **10** proceeds. The relative distance between the probe **40** and the conductors **20**, **22** at any given reception point **26** is termed the induction distance. The maximum allowable induction distance is a function of the power output of the transmitting unit **12**, the size and configuration of the pickup coil, and the voltage of the locator and carrier signals in the conductors **20**, **22**. A typical maximum allowable induction distance is up to about 1 meter using the relatively large balanced pickup coil **82** for inaccessible buried paired cable and up to about 0.06 meters using the relatively small unbalanced pickup coil **186** for accessible paired cable.

The locator and carrier signals travel along the conductors **20**, **22** to the reception point **26**, where the locator and carrier signals induce induced locator and carrier signals in the balanced pickup coil **82** of the receiving unit **14**. Since the spacing between the first and second coil segments **84**, **86** is equal to one half the length of the lay of the paired line **16**, the balanced pickup coil **82** sees two adjacent half lengths of the lay of the paired line **16** at any given reception point **26**. Thus, a first induced locator signal is induced in the first coil segment **84** and a second induced locator signal of opposite polarity is induced in the second coil segment **86**. The first and second coil segments **84**, **86** are electrically coupled with the first and second balancing inlet pathways **104** and **106** to receive the induced locator signals of opposite polarity and sum the signals in the balancing amplifier **108**. In contrast, background noise from sources such as nearby power lines (not shown) not having a 36 inch lay length induces induced noise signals of the same polarity in each coil segment **84**, **86**, which cancel in the balancing amplifier **108**. Consequently, the balancing amplifier **108** outputs a balanced induced locator signal in response to the first and second induced locator signals, but is unresponsive to induced noise signals.

The specific configuration of the induced locator signal balancing/amplifying circuit **97** enhances the ability of the device **10** to reject interfering signals from the surroundings, while processing desired signals from the paired line **16**. In particular, the induced locator signal balancing/amplifying circuit **97** is perfectly balanced when the first resistance ratio, defined as the resistance of the balancing resistor **110***a* divided by the resistance of the balancing resistor **110***b*, exactly equals the second resistance ratio, defined as the resistance of the balancing resistor **116***a* divided by the sum of the resistances of the balancing resistor **116***b* and the balancing potentiometer **120**. The resistances of the balancing resistor **116***b* and the balancing potentiometer **120** are selected such that the induced locator signal balancing/amplifying circuit **97** is in perfect balance when the balancing potentiometer **120** is positioned at the center of its range. If an extraneous signal induces induced noise signals of equal polarity, but differing voltages, in the respective coil segments **84**, **86**, the balancing potentiometer can be offset to compensate for the voltage difference. As a result, the two induced noise signals can be summed to zero and canceled in the balancing amplifier **108** even when the voltages of the induced noise signals in the coil segments **84**, **86** are not identical.

The balanced induced locator signal is transmitted from the induced locator signal balancing/amplifying circuit **97** to the induced locator signal processing circuit **98**, while the induced carrier signal is transmitted from the pickup coil **82** to the induced carrier signal processing circuit **100**. Specifically, the induced carrier signal is transmitted via the receiving circuitry outlet line **174** to the carrier signal amplifier/receiver **166**, which amplifies and filters the induced carrier signal. The carrier signal limiter **168** subsequently limits the amplitude of the amplified signal. The synchronization signal output **170** demodulates the induced carrier signal, producing a synchronization signal that is transmitted from the synchronization signal output **170** to the phase shifter **152** of the induced locator signal processing circuit **98**. If necessary, the phase shifter **152** corrects any phase irregularities in the synchronization signal caused by demodulation. The phase shifter **152** has a split outlet **156**, such that the synchronization signal is transmitted in parallel to the real synchronous oscillator **162** and the quadrature synchronous oscillator **164**. The real synchronous oscillator **162** produces a real synchronization signal that is in phase with the synchronization signal and transmits the real synchronization signal to the real synchronous detector **134**. The quadrature synchronous oscillator **164** similarly produces a quadrature synchronization signal that is 90° out of phase with the synchronization signal and transmits the quadrature synchronization signal to the quadrature synchronous detector **140**.

The balanced induced locator signal is transmitted to the induced locator signal processing circuit **98** through the first switch **122**, which the operator has manually placed in an up position corresponding to a resistive short fault detection mode of operation. The voltage of the balanced induced locator signal is further amplified in the variable gain amplifier **124** and, if desired, adjusted for differences in the signal due to fault resistance losses. The band pass filter **126**, which is tuned to the relatively low frequency of the balanced induced locator signal, rejects extraneous signals from the output of the variable gain amplifier **124** that have surrounding frequencies. In particular, the band pass filter **126** attenuates interference from 50/60 Hz signals that are magnetically induced onto the paired line **16** by adjacent power lines.

The balanced induced locator signal, which is output from the band pass filter **126**, is split and fed in parallel to the real component pathway **130** and the quadrature component pathway **132** of the induced locator signal processing circuit **98**. The balanced induced locator signal may be characterized as comprising a real component and a quadrature component, one or both of which may be present in the balanced induced locator signal at any given time during operation of the device **10**. The real component is resistive current that is in phase with the voltage of the locator signal generated in the transmitting unit **12**. The quadrature component is capacitive current that leads the voltage of the locator signal generated in the transmitting unit **12** by 90°. Accordingly, the real component pathway **130** and quadrature component pathway **132** detect and segregate the respective components of the balanced induced locator signal, based on phase synchronization. The real synchronous detector **134** utilizes the real synchronization signal to detect only the presence of the real component, which corresponds to the current of the locator signal flowing through the fault resistance, and to reject any carry-by occurring due to current flow into pair capacitance or conductor-to-ground capacitance. The quadrature synchronous detector **140** conversely utilizes the quadrature synchronization signal to detect only the presence of the quadrature component, which corresponds to current flow into capacitance, and to reject the current flowing through the fault resistance or leakage on the conductor. The real low pass filter **136** filters the rectified DC signal from the real synchronous detector **134**, allowing a narrowing of the circuit bandwidth to more effectively filter out 50/60 Hz signals and other extraneous signals having undesired frequencies. The quadrature low pass filter **142** similarly filters the rectified DC signal from the quadrature synchronous detector **140**.

Since the present fault **18** is a resistance fault, the operator has manually placed the second switch **138** in an up position, enabling the resistive short fault detection mode of operation. The second switch **138** electrically couples the real low pass filter **136** with the indicator output **144** of the induced locator signal processing circuit **98**. The real component is transmitted to the indicator output **144** which operates in correspondence with the presence and magnitude of the real component to communicate a fault indicator to the operator. In particular, the output oscillator **150**, which is an audio voltage control oscillator, and the audio speaker **148** generate an audible correlation of the real component in the form of a continuous audible tone having an intensity or frequency directly related to the presence and voltage magnitude of the real component. As the magnitude of the real component increases, the intensity or frequency of the tone generated by the speaker increases. Correspondingly, as the magnitude of the real component decreases, the intensity or frequency of the tone generated by the speaker decreases.

When the receiving unit **14** approaches the resistive short fault **18** from the transmission point **24**, the receiving unit **14** detects voltage due to current flow in the fault resistance. The magnitude of this voltage may rise and fall and reverse in polarity as the pickup coil **82** is moved along the paired cable containing the paired line **16** due to the twist of the conductors **20, 22** and the spiraling of the paired line **16** within the paired cable, but will remain continuous before the fault **18** is reached. Polarity changes can be communicated to the operator by a change in a characteristic of the audible tone generated by the output oscillator **150** in correspondence with polarity changes. In any case, when the receiving unit **14** passes the fault **18**, the receiving unit **14** no longer detects any voltage. Thus, the fault **18** in the paired line **16** is located by moving the receiving unit **14** along the paired line **16** away from the transmission point **24** in the direction of the fault **18** to establish incrementally new reception points **26**. The fault **18** is precisely located at the point on the paired line **16** where the intensity or frequency of the tone from the speaker **148** is strong followed by an abrupt drop in the intensity or frequency of the tone as the receiving unit **14** continues along the paired line **16**. The display **146** provides a quantitative visual verification of the information communicated to the operator by the speaker **148**. The display **146** is a visual correlation of the magnitude of the real component in the form of either an analog or a digital readout of the values of the magnitude as the receiving unit **14** is moved along the paired line **16**.

Although voltage is selected herein as the characteristic of the induced locator signal which is quantified by the indicator output **144** to enable fault location, it is apparent to the skilled artisan that an alternate characteristic of the induced locator signal can be selected for quantification, such as phase shift, to enable fault location within the scope of the present invention.

The principle by which the real synchronous detector **134**, and correspondingly the quadrature synchronous detector **140**, operate is described with reference to FIGS. **5***a*, **5***b* and **5***c*. Operation of the real synchronous detector **134** in association with the fault locating device **10** of FIG. **1** is the functional equivalent of a circuit **194** shown in FIG. **5***a*. The circuit **194** has a switch **196** that is opened and closed in synchronism with the induced locator signal in the receiving unit **14**. The circuit **194** further includes a series resistor **198** and, in parallel, a resistor **200**, a capacitor **202** and an amplifier **204** such that the output voltage of the circuit **194** is the average input voltage of the circuit **194** when the switch **196** is closed. The switch **196** is opened and closed as shown in FIG. **5***b* by the switch waveform **206**. FIG. **5***c* shows the input voltage waveform of the circuit **194** as the sum of two distinct waveforms, a resistance current waveform **208** and a capacitance current waveform **210**.

By opening and closing the switch **196** in synchronism with the input voltage waveform, in accordance with the relationship shown in FIGS. **5***b* and **5***c*, the capacitance current waveform **210** of the carry-by leads the resistance current waveform **208** by 90°, thereby averaging to zero as indicated by the shaded area under the capacitance current waveform **210** of FIG. **5***c*. In contrast, the entire fault resistance current waveform **208** is in phase with the induced locator signal and the switch waveform **206**, thereby enabling detection of the resistance fault.

Synchronous operation of the receiving unit **14** and transmitting unit **12** in conjunction with the use of locator signals having a relatively low frequency enables the effective location of faults having resistances above 50 kohms without a significant impact from carry-by, even in relatively long paired lines **16** having lengths of 5000 meters or more. Low frequency operation tends to decrease carry-by because lowering the frequency of the locator signal increases the capacitive reactance of the paired line **16**, reducing the magnitude of locator signal current flow past the fault **18**. The low frequency locator signal has the added advantage of exhibiting substantially less attenuation over length of the paired line **16** than would a higher frequency locator signal. Synchronous detection further enables the operator to observe changes in polarity due to twisting of the conductors **20, 22**. This permits the operator to differentiate between carry-by and the locator signal in the presence of unbalanced conductor faults and ground faults both of which are more susceptible to carry-by than balanced conductor faults.

In another embodiment of the present method, the fault **18** is characterized as an open fault, which is generally defined herein to include a splice containing a bridge tap, i.e., a conductor bridged onto the main conductor. The operator manually repositions the second switch **138** in a down position, enabling the open fault detection mode of operation. The second switch **138** electrically couples the quadrature low pass filter **142** with the indicator output **144** of the induced locator signal processing circuit **98**. The quadrature low pass filter **142** filters the rectified DC signal from the quadrature synchronous detector **140** in substantially the same manner as the real low pass filter **136**. The quadrature component is transmitted to the indicator output **144**. The indicator output **144** operates in correspondence with the presence and magnitude of the quadrature component in substantially the same manner as described above with respect to the real component to locate the position of the open fault on the paired line. Location of the bridged tap is alternately enabled because the bridged conductor draws capacitive currents, which are monitored when the device **10** is configured to locate open faults. When the receiving unit **14** passes a splice in the paired line **16** containing a bridged tap, there is an abrupt drop in the magnitude of capacitive current flowing through the paired line **16**, producing a corresponding abrupt drop in the audible or visual fault indicator.

In an alternate method of operating the fault locating device **10**, a cable shield break is located in a cable having at least one conductor surrounded by a shield. Referring to FIG. **6**, a cable **212** is shown, to which the present method of locating a shield break is applicable. The cable **212** has a shield **214** and at least one continuous concentric wire enclosed thereby as a conductor **216**. It is understood that additional continuous wires may also be present within the shield **214** to provide the cable **212** with multiple conductors. Referring additionally to FIG. **3**, the method is performed by installing the unbalanced pickup coil **186** of FIG. **4** in the receiving unit **14** and manually placing the first switch **122** in the down position to connect the capacitive signal processing circuit **102** with the induced locator signal processing circuit **98**. The conductor **216** is grounded to the cable shield **214** at both ends (not shown) of the cable **212** and a locator signal is sent by the transmitting unit **12** along the conductor **216** of the cable **212**. When the shield **214** is broken, the locator signal flowing in the conductor **216** generates a longitudinal voltage on the cable shield **214** which is normally shorted to earth at each shield ground connection. However, in the case of a shield break, the voltage builds up on the shield **214** at the point of the break.

The unbalanced pickup coil **186**, which is a capacitive pickup functioning as a capacitor, impresses a capacitive signal onto the receiving unit common **95** through the third coil outlet line **94** in response to the voltage on the cable shield **214** as the receiving unit **14** is moved along the length of the cable **212**. It is noted that the receiving unit common **95** is floating ungrounded within the insulated receiving unit housing **44**. The ground pickup **180** is grounded, for example, by capacitively coupling with the operator, who in turn is coupled with the earth through his feet. Accordingly, the capacitive signal that appears in the pickup coil **186** is received by the capacitive amplifier **182** via the receiving unit common **95**. The capacitive amplifier **182** amplifies the difference between the capacitive signal and the ground reference received via the ground pickup **180**. The resulting differential capacitive signal is sent to the induced locator signal processing circuit **98** for evaluation. Since the capacitive signal reverses polarity across the shield break (not shown) and is al: a maximum level when the receiving unit **14** is adjacent to the shield break, the speaker **148** and/or display **146** communicate the level of the differential capacitive signal to the operator along the length of the cable **212**, thereby enabling precise location of the shield break within the cable **212**.

Although the unbalanced pickup coil **186** is described as the capacitive pickup herein, the present invention is not so limited. It is apparent to the skilled artisan that substantially any component functioning as a capacitive plate can serve as the capacitive pickup within the scope of the present invention.

While the forgoing preferred embodiments of the invention have been described and shown, it is understood that alternatives and modifications, such as those suggested and others, may be made thereto and fall within the scope of the invention.

I claim:

1. A device for locating a fault in a paired line comprising:

means connectable to a first point on a paired line for generating and introducing a locator signal into said paired line;

means connectable to said first point for generating and introducing a carrier signal into said paired line, wherein said carrier signal includes synchronization of said locator signal generating means;

means positionable at a second point on said paired line for creating an induced locator signal in response to said locator signal;

means positionable at said second point on said paired line for creating an induced carrier signal including said synchronization in response to said carrier signal;

means responsive to said induced locator signal and said induced carrier signal for detecting a component of said induced locator signal indicative of a fault; and

means for communicating an indicator of said component to an operator, wherein said communicated indicator enables location of said fault in said paired line.

2. The device of claim **1** wherein said locator signal generating means is a first locator signal generating means connectable to a first conductor at said first point for generating and introducing said first locator signal into said first conductor, said device further comprising a second means connectable to a second conductor at said first point on said paired line for generating and introducing a second locator signal into said second conductor.

3. The device of claim **1** wherein said induced locator signal creating means is a first induced locator signal creating means positionable at said second point on said paired line for creating said first induced locator signal in response to said locator signal, said device further comprising a second means positionable at said second point on said paired line for creating a second induced locator signal in response to said locator signal.

4. The device of claim **3** further comprising means for creating a balanced induced locator signal from said first and second induced locator signals.

5. The device of claim **1** wherein said component is a first component corresponding to a real phase of said locator signal generating means and said induced locator signal has a second component corresponding to a quadrature phase of said locator signal generating means, further wherein said detection means is a first detection means for detecting said first component, said device further comprising a second detection means for detecting said second component.

6. The device of claim **5** wherein said synchronization includes real synchronization and quadrature synchronization, said device further comprising means for generating and transmitting a real synchronization signal corresponding to said real synchronization to said first detection means and means for generating and transmitting a quadrature synchronization signal corresponding to said quadrature synchronization to said second detection means.

7. The device of claim **5** further comprising means for selecting said first component to the exclusion of said second component or selecting said second component to the exclusion of said first component aid transmitting said selected component to said indicator communicating means.

8. A device for locating a fault in a paired line comprising:

a locator signal output connectable to a first point on a paired line to generate a locator signal for transmission through said paired line to a second point on said paired line;

a carrier signal output connectable to said first point on said paired line to generate a carrier signal including synchronization for transmission through said paired line to a second point on said paired line;

a pickup coil movably positionable at said second point on said paired line to create an induced locator signal having at least one component indicative of a fault and to create an induced carrier signal including said synchronization;

a detector in electrical communication with said pickup coil to detect said at least one component; and

a synchronization signal output in electrical communication with said detector to create a synchronization signal corresponding to said synchronization included in said induced carrier signal.

9. The device of claim **8** wherein said detector is a first detector to detect a first component of said locator signal indicative of said fault to the exclusion of a second component of said locator signal indicative of said fault, said device further comprising a second detector to detect said second component to the exclusion of said first component.

10. The device of claim **9** further comprising a switch in selective electrical communication with said first detector or said second detector, and an audio speaker or a display responsive to said first component or said second component.

11. The device of claim **8** wherein said induced locator signal is a first induced locator signal, and further wherein said pickup coil has a first coil segment to create said first induced locator signal and a second coil segment to create a second induced locator signal in response to said locator signal generated by said locator signal output.

12. The device of claim **8** wherein said locator signal is a first locator signal, said device further comprising a locator signal transformer having a first outlet winding to deliver said first locator signal to said paired line and a second outlet winding to deliver a second locator signal of opposite polarity to said paired line.

13. The device of claim **11** further comprising an induced locator signal balancing circuit to produce a balanced induced locator signal in response to said first and second induced locator signals.

14. The device of claim **13** wherein said locator signal balancing circuit includes a balancing amplifier and a balancing potentiometer positioned in parallel.

15. The device of claim **9**, further comprising a real synchronous oscillator in electrical communication with said first detector to transmit a real synchronization signal to said first detector and a quadrature synchronous oscillator in parallel with said real synchronous oscillator and in electrical communication with said second detector to transmit a quadrature synchronization signal to said second detector.

16. The device of claim **8** wherein said locator signal output is a locator signal oscillator.

17. The device of claim **8** wherein said carrier signal output is a carrier signal oscillator.

18. The device of claim **8** wherein said synchronization signal output is a demodulator.

19. A method for locating a fault in a paired line comprising:

a) generating a locator signal and a carrier signal including synchronization at a first point of a paired line, wherein said paired line has a fault;

b) electrically introducing said locator signal and said carrier signal into said paired line at said first point;

c) creating an induced locator signal and an induced carrier signal including synchronization at a second point on said paired line in response to said locator signal and said carrier signal;

d) detecting a component of said locator signal indicative of said fault; and

e) communicating an indicator of said component to an operator, wherein said communicated indicator enables location of said fault in said paired line.

20. The method of claim **19** wherein said locator signal is a first locator signal introduced into a first conductor at said first point and said method further comprises generating and electrically introducing a second locator signal into a second conductor at said first point on said paired line.

21. The method of claim **19** wherein said induced locator signal is a first induced locator signal created in response to said locator signal and said method further comprises creating a second induced locator signal in response to second locator signal.

22. The method of claim **21** further comprising balancing said first and second induced locator signals to produce a balanced induced locator signal.

23. The method of claim **19** wherein said component is a first component corresponding to a real phase of said locator signal and said locator signal has a second component indicative of said fault corresponding to a quadrature phase of said locator signal, said method further comprising detecting said second component.

24. The method of claim **23** further comprising segregating said first component from said second component.

25. The method of claim **19** wherein said synchronization includes real synchronization and quadrature synchronization, said method further comprising creating a real synchronization signal from said real synchronization to detect said first component and creating a quadrature synchronization signal from said quadrature synchronization to detect said second component.

26. The method of claim **23** further comprising selecting said first component to the exclusion of said second component or selecting said second component to the exclusion of said first component, wherein said indicator corresponds to said selected component.

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